Differential Pumping with an Insert of a Narrow Aperture in the PIP2IT MBET

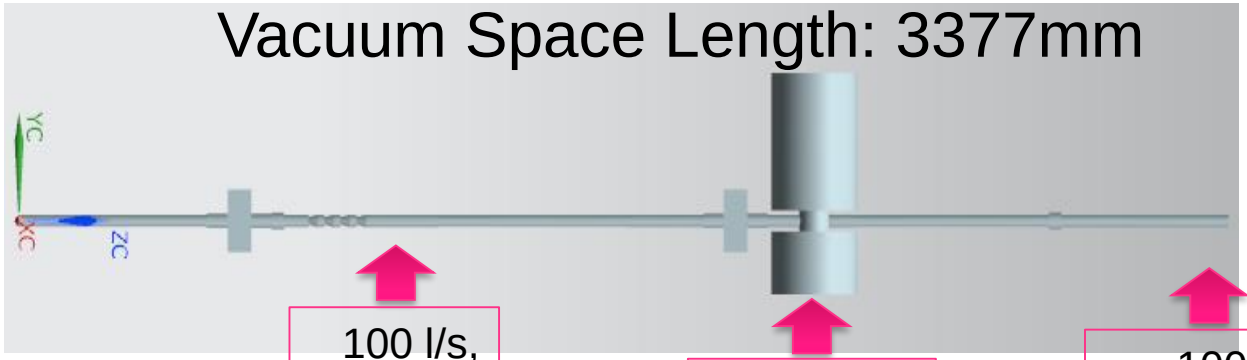
Alex Chen on behalf of the PIP2IT task force:

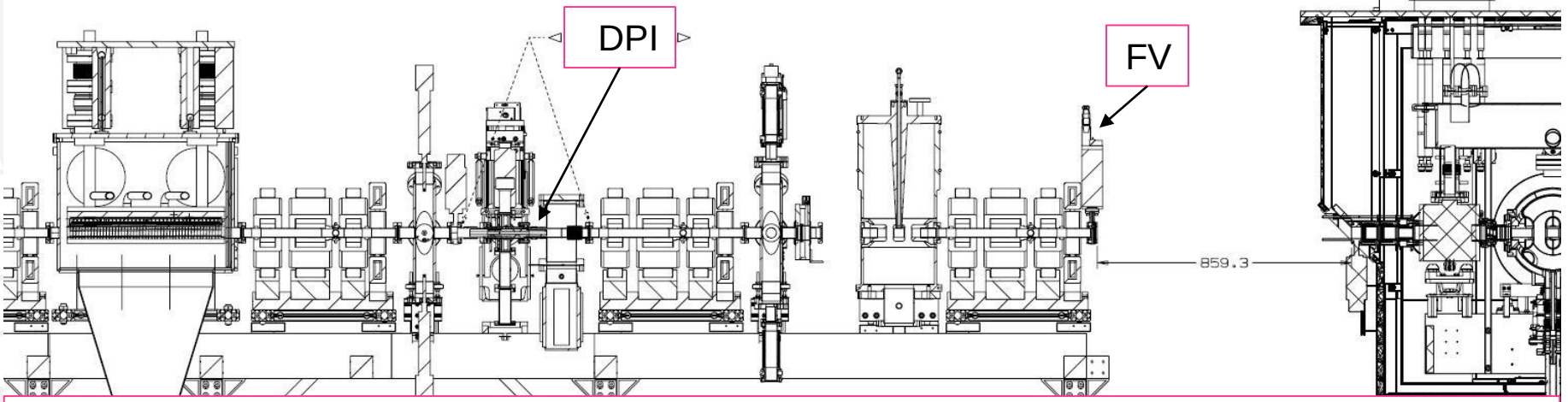
Outline

- Motivation and Layout MEBT of Absorber to HWR(DP section)
- Function Requirement
- Design of DPI
  - Mechanical solution
  - Vacuum solution
  - Electrical solution
  - Thermal solution
- DPI-FV Vacuum test setup
- Vacuum Test results
- Summary

DP Layout (Absorber to HWR)

1) Gas(H_2) Flux from Absorber:
1E-5mbar.l/s
2) Uniform outgassing rate:
1e-10 starts, 1e-11 ultimate





The primary purpose of differential pumping section is to minimize the gas flux and particulates from MEBT to HWR during operation or vacuum failure in MEBT

FRS of DPI (ED0004472)

- DPI Requirments

Parameters	Value	Units
Position alignment of the DPI tube with respect to beam line axis	≤ 0.5	mm
Angular alignment with respect to beam line axis*1	≤ 2	mrad
Cooling	Natural air convection	
Maximum average power	25	W
Maximum pulse energy deposition*2	0.4	J
Electrical isolation with respect to ground	300	V
Maximum current to report (CW/tuning)	20 /200	µA
Current reading accuracy *3 (CW/tuning)	≤ 1 / 10	µA
*Accident detection: minimum trip level*4		
Averaged over 5 µs	100	µA
Averaged over 1/60 s =16.6 ms	5	µA

- Relevant beam parameters

Parameters	Value	Units
Ion type	H-	
Beam energy	2.1	MeV
Operation mode		
Nominal beam size at DPI (6σ), X/Y	8/8	mm
Maximum beam current, CW	10	mA
Tuning mode		
Pulse repetition rate	Hz	20
Pulse length	µs	20
Maximum pulse beam current	10	mA

- Recommended DPI Parameters

Parameters	Value	Units
Material of beam – exposed portion of DPI tube	copper	
Minimum diameter of DPI tube	10	mm
Length of DPI tube	200	mm
Ion pump speed	100	l/s

Mechanical

- Insertion length with Ion Pump: 435mm
- Positioning

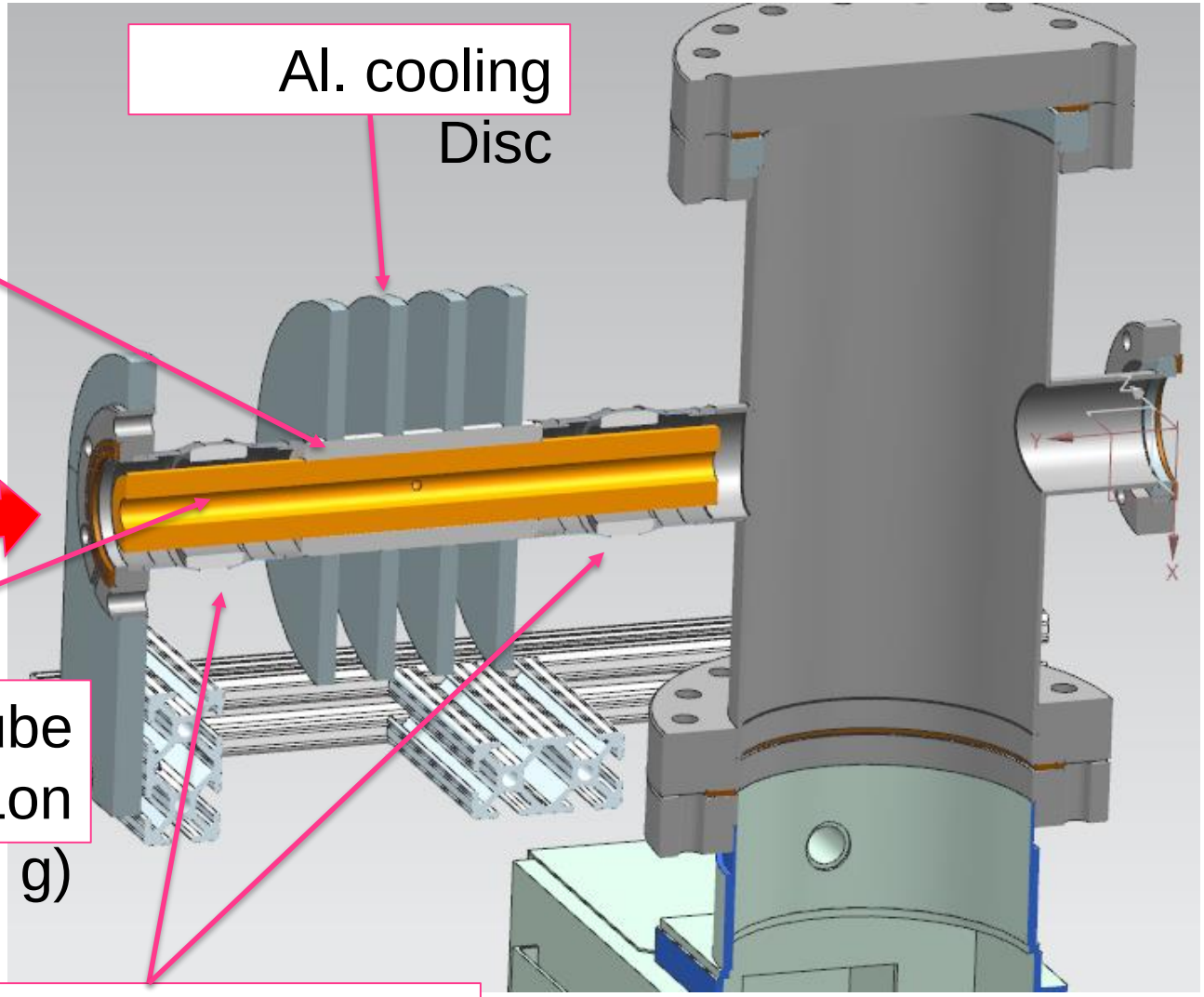
Position alignment of the DPI tube with respect to beam line axis	≤ 0.5	mm
Angular alignment with respect to beam line axis*[1]	≤ 2	mrad

  - DPI is supported common girder with adjustment
  - Position of aperture is determined by aligning cooling disc OD

Vacuum considerations

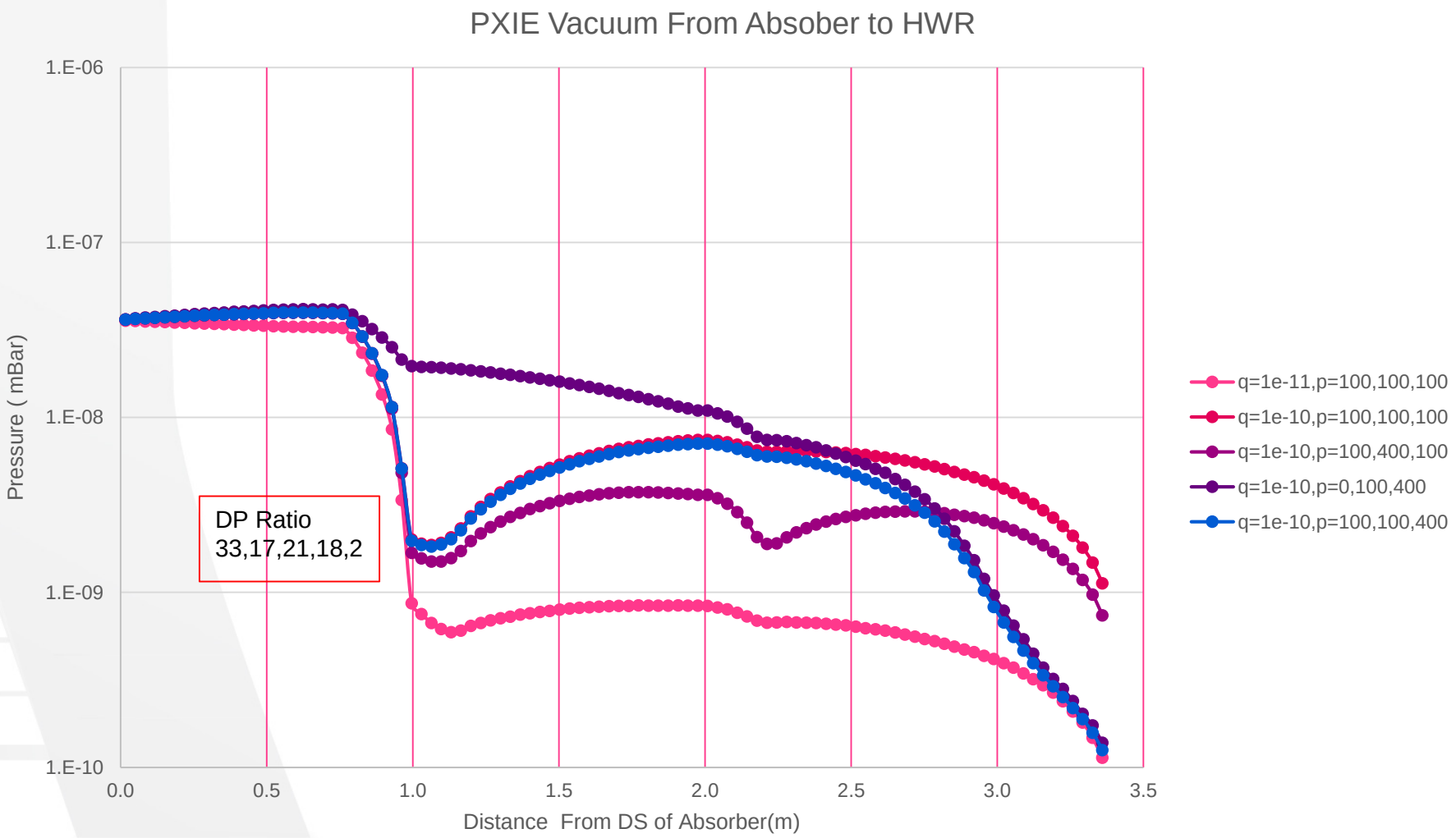
- Absorber is high outgassing of Hydrogen (at level of 10^{-4} torr.l/s) and loose particles
- Uniform outgassing rate applied inner surfaces of SS and Copper
- Pump distribution studied
- Distance of DPI-IP studied
- Pressure ratio of before/after DPI calculated
- Detail Results show in ppt of Molflow+ Simulation

Design of DPI

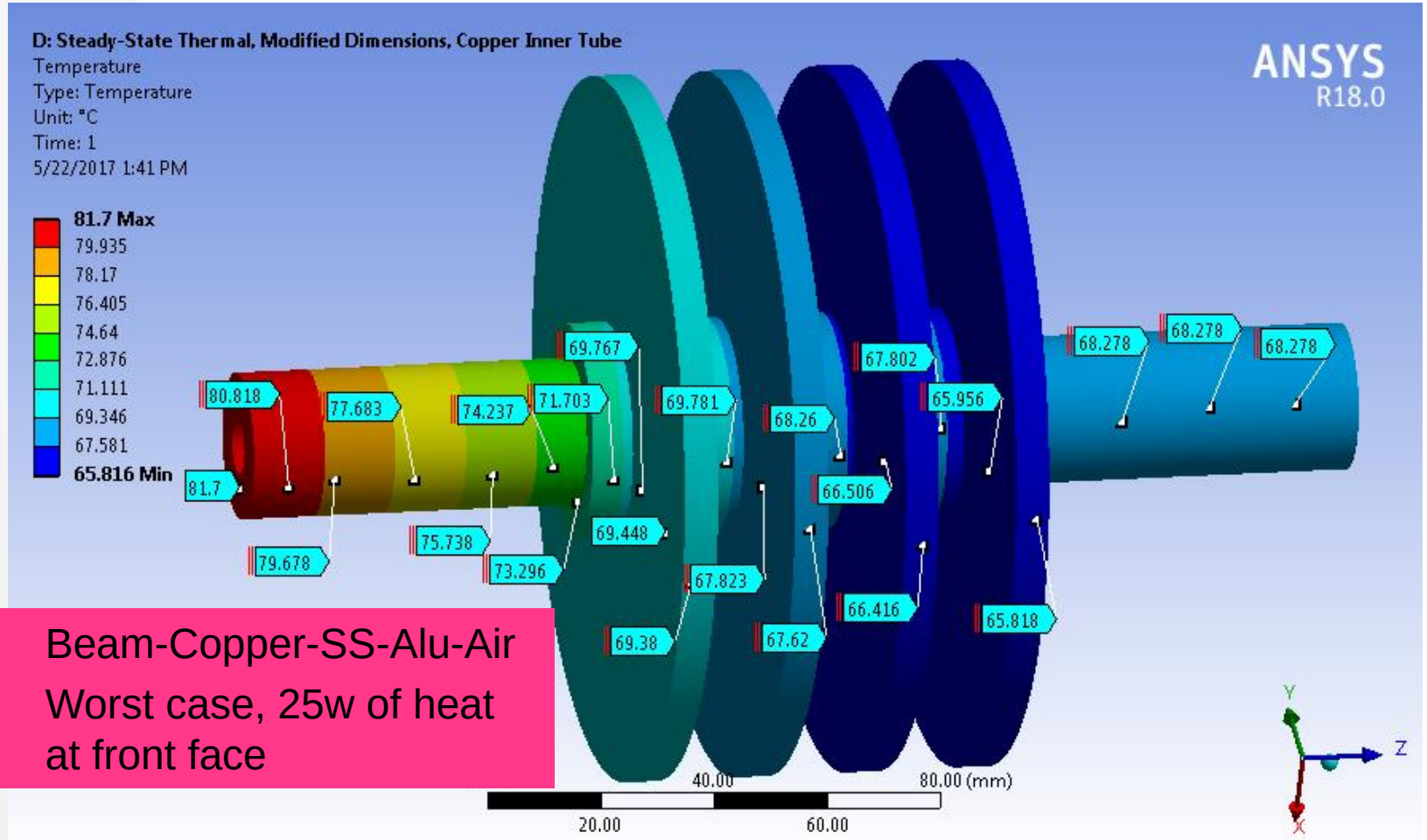


Pressure Profile by MolFlow Simulation

(Absorber to HWR，1E-5 mbar.l/s H2，)



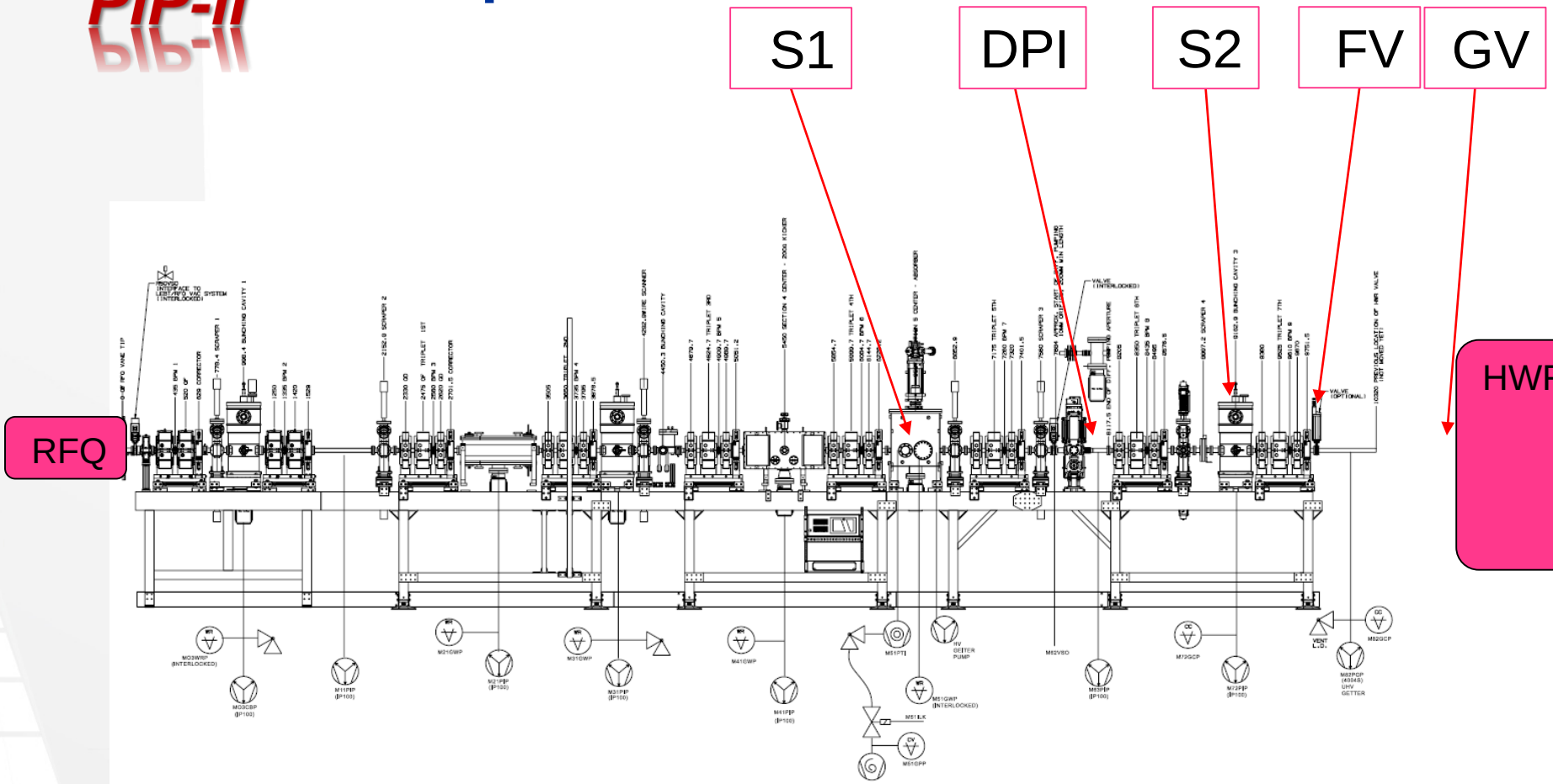
Thermal solution



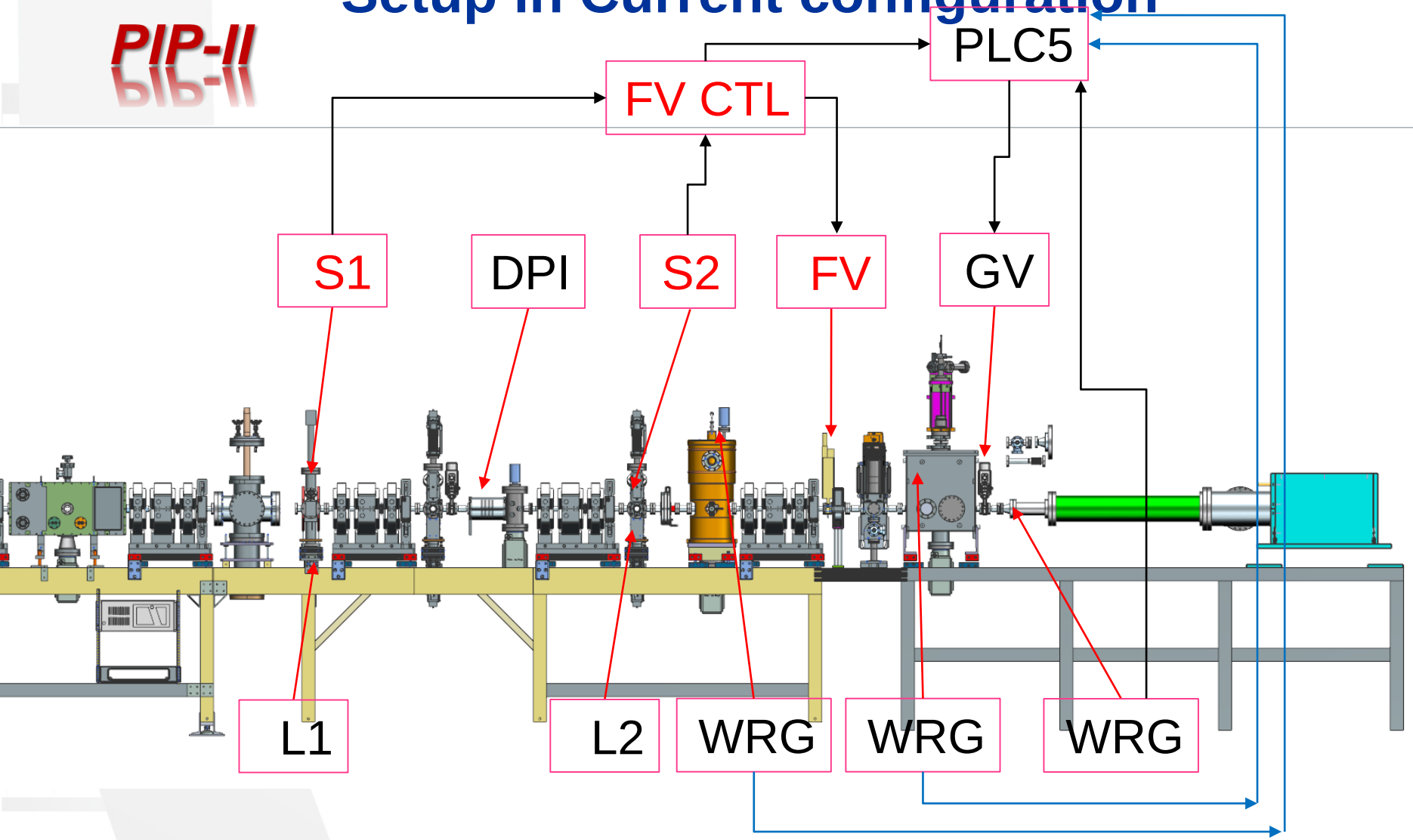
- Beam-Copper-SS-Alu-Air
- Worst case, 25w of heat at front face

Analyses were done on 1)material choices of inner tube, 2)heating distributions, 3)relative longitudinal positions

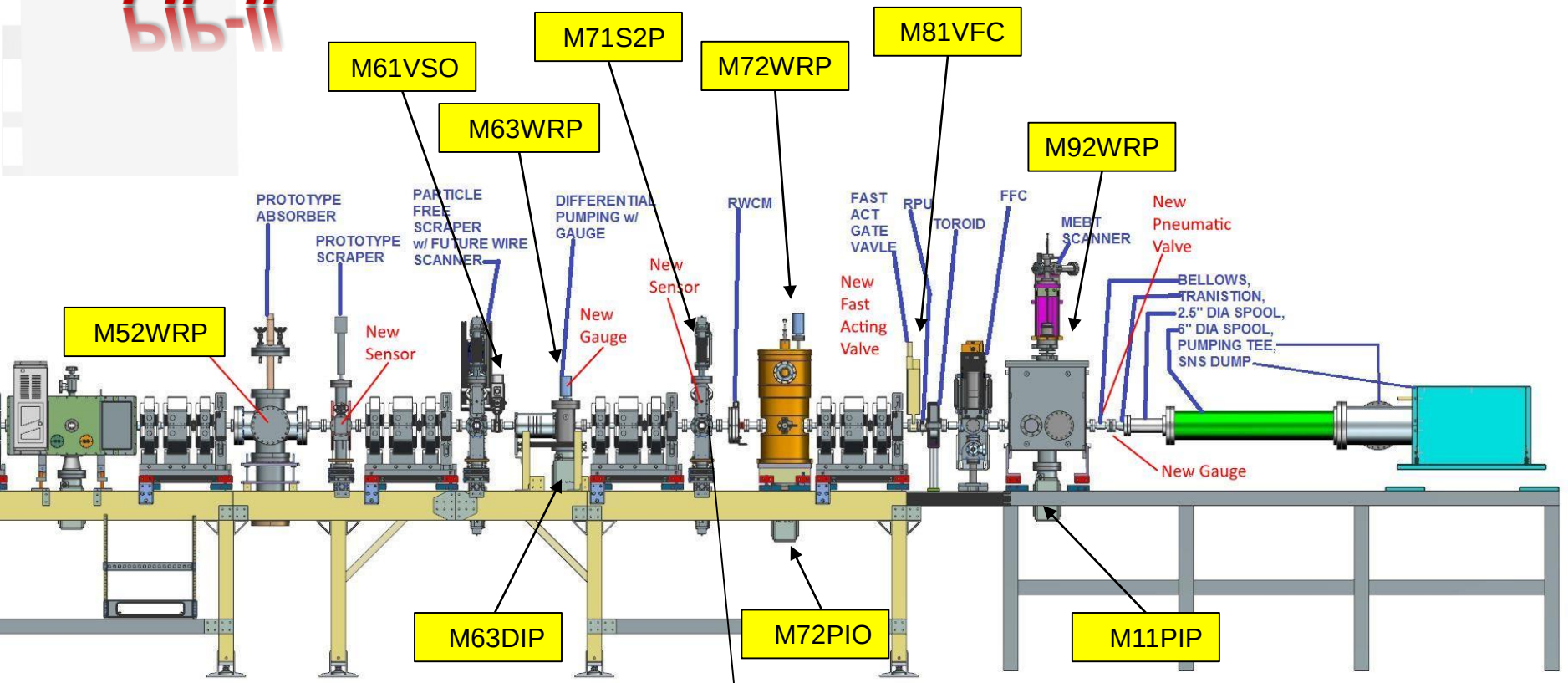
Setup in final locations



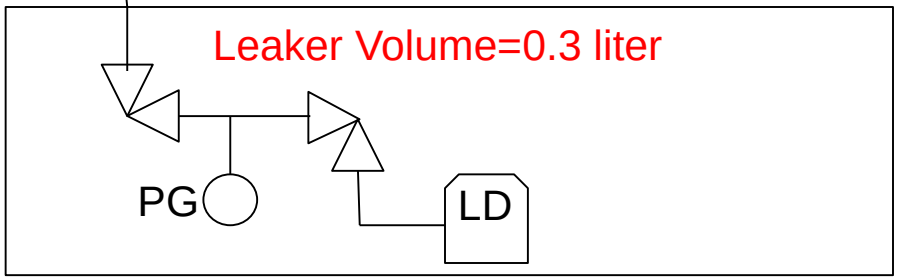
Setup in Current configuration



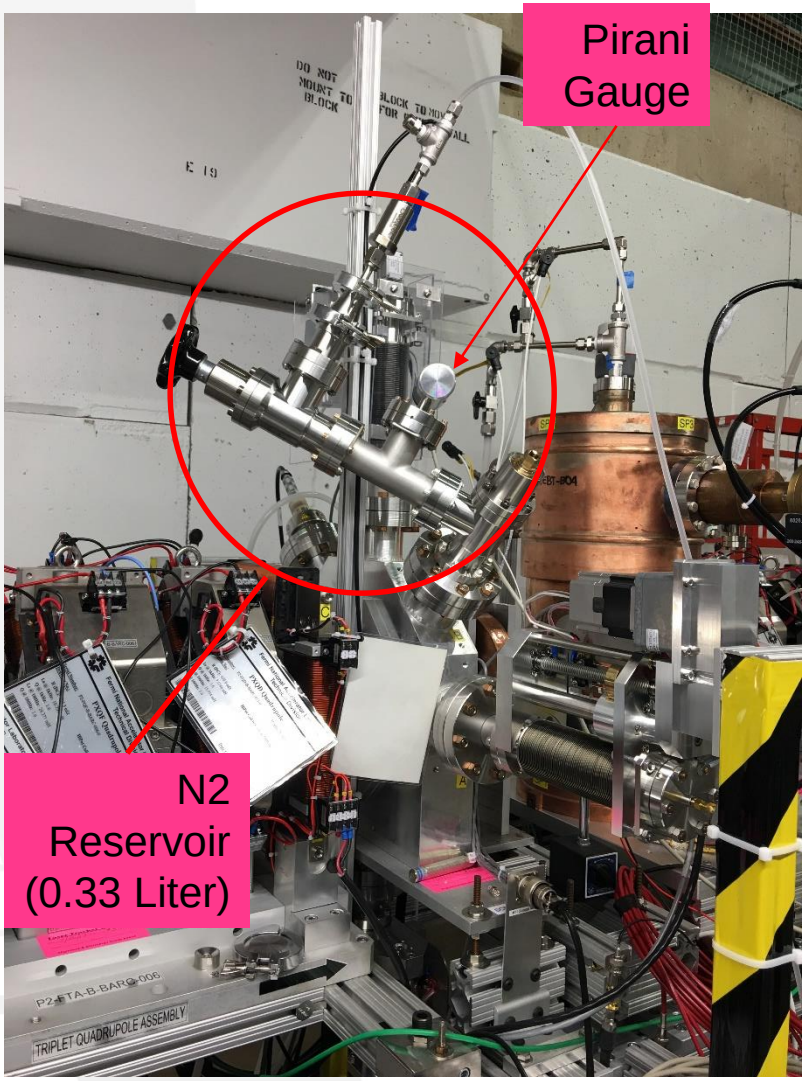
1st Test on MEBT DPI-FV

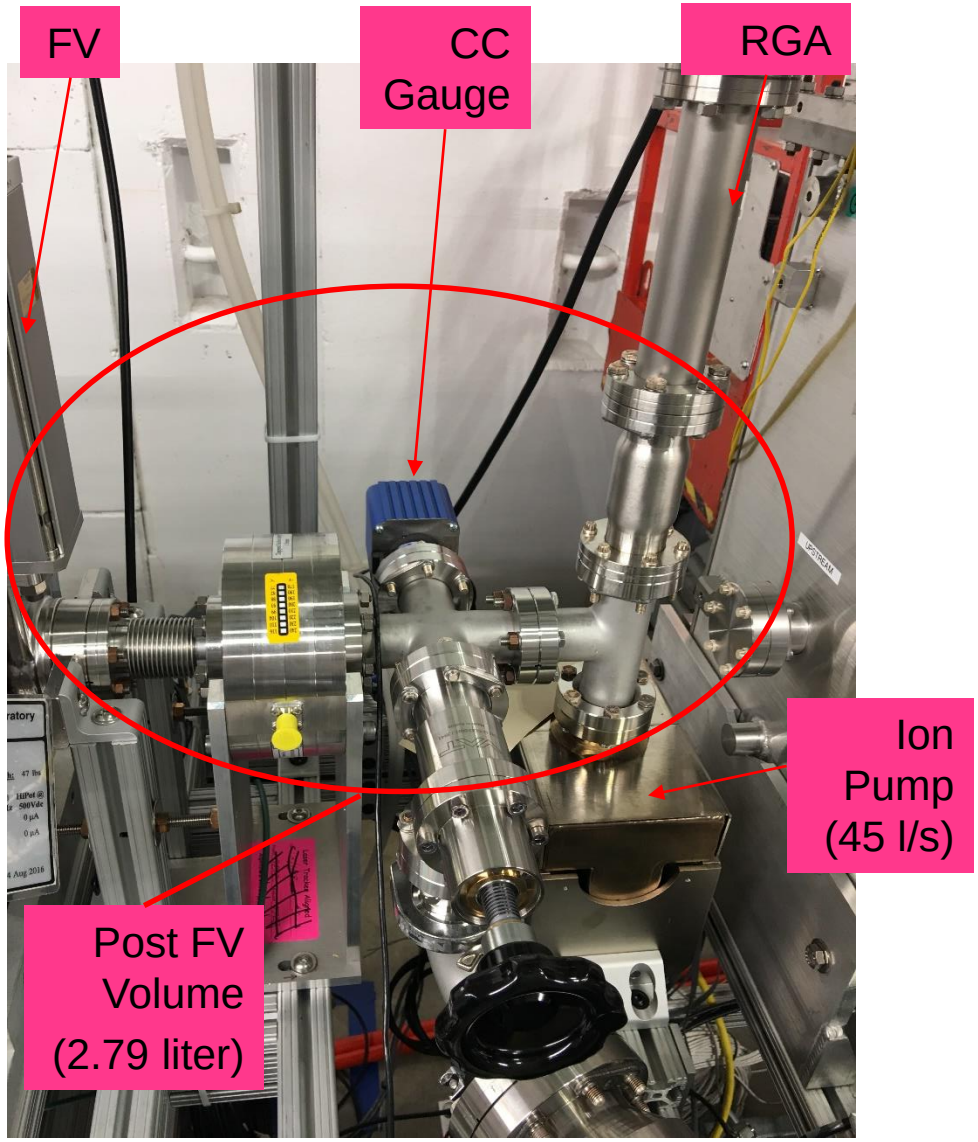


1. V1=36.5 liters(M61VSO-FV)
2. V2=95.1 liters(POST FV)
3. Permeation rate from Scanner O-Ring is about 6E-7 torr.l/s



Setup of Test





With current 45 l/s, 3E-9 torr has been achieved without baking

Differential Pumping Effect

Pressure rise at US of DPI

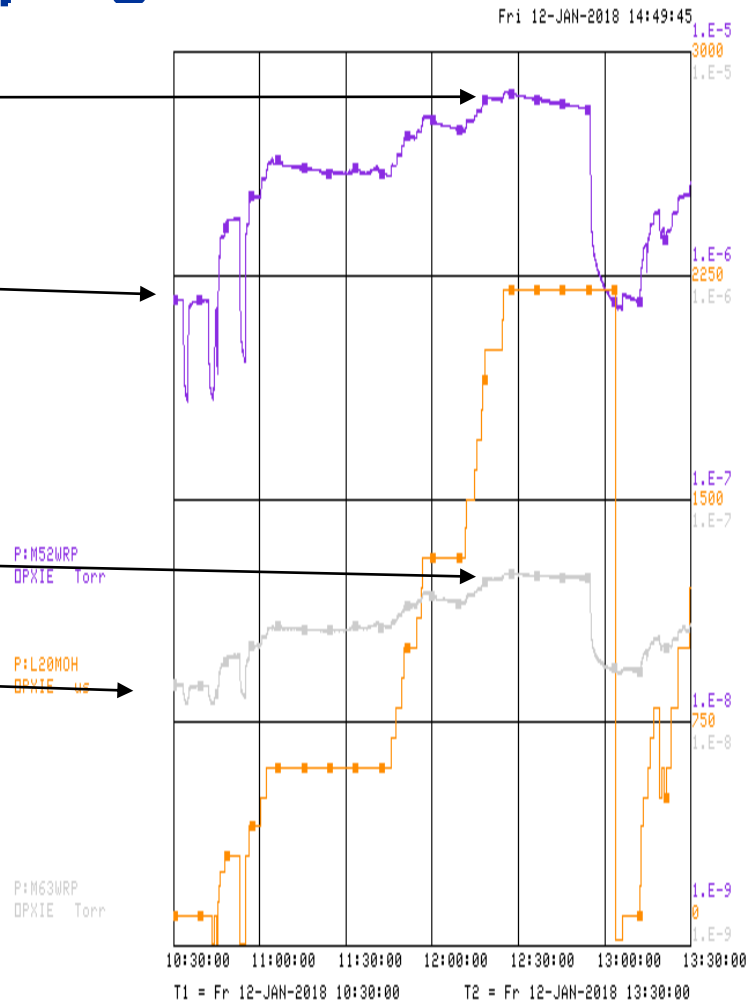
6.6E-6

7.6E-7

Pressure rise DS of DPI

4.6E-8

1.5E-8



With current setup of DPI and IPs,

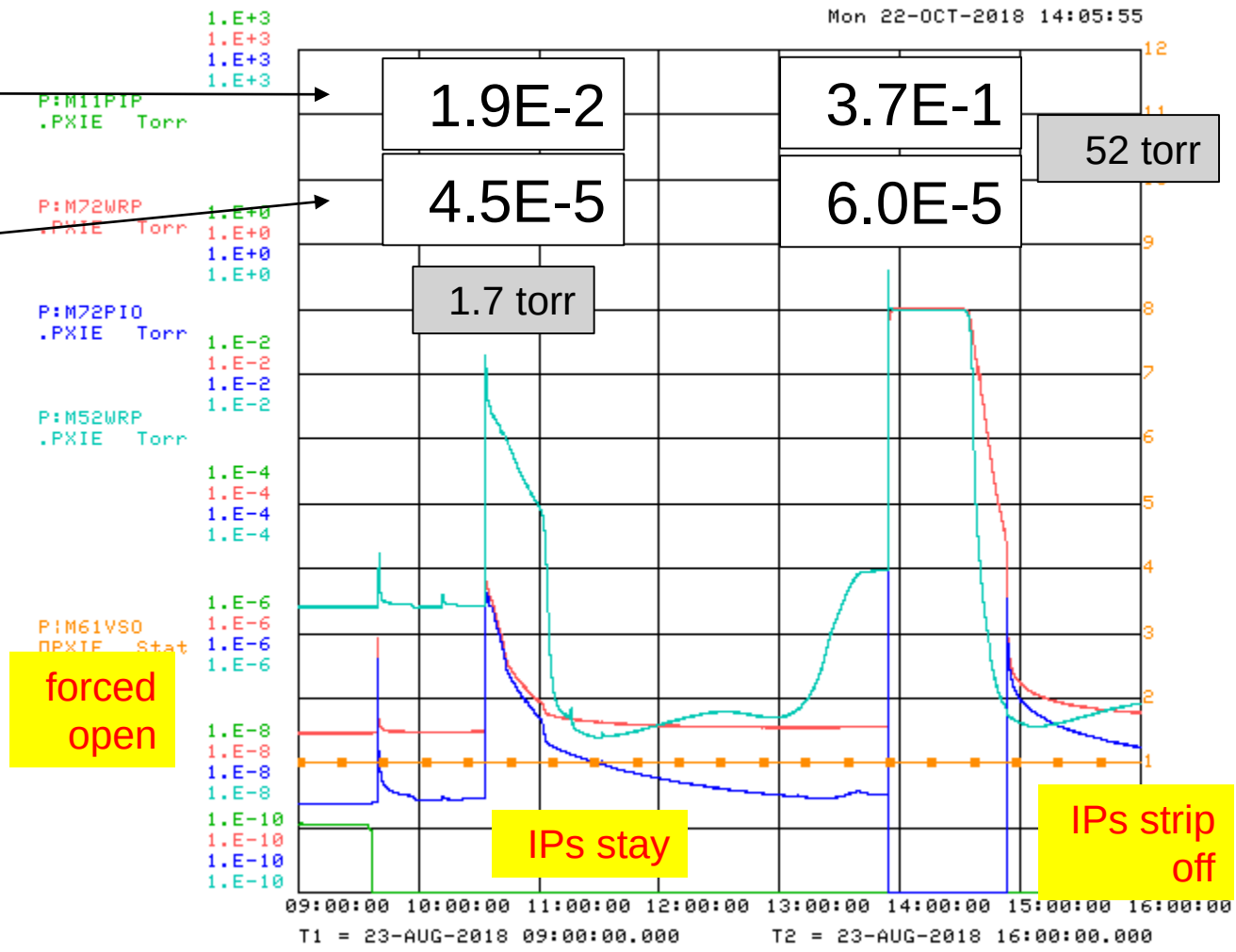
DP_{us}/DP_{ds} =188

Vacuum Gauge reading on Beamline *(Leak From Upstream of DPI)*

Pressure rise at US of DPI

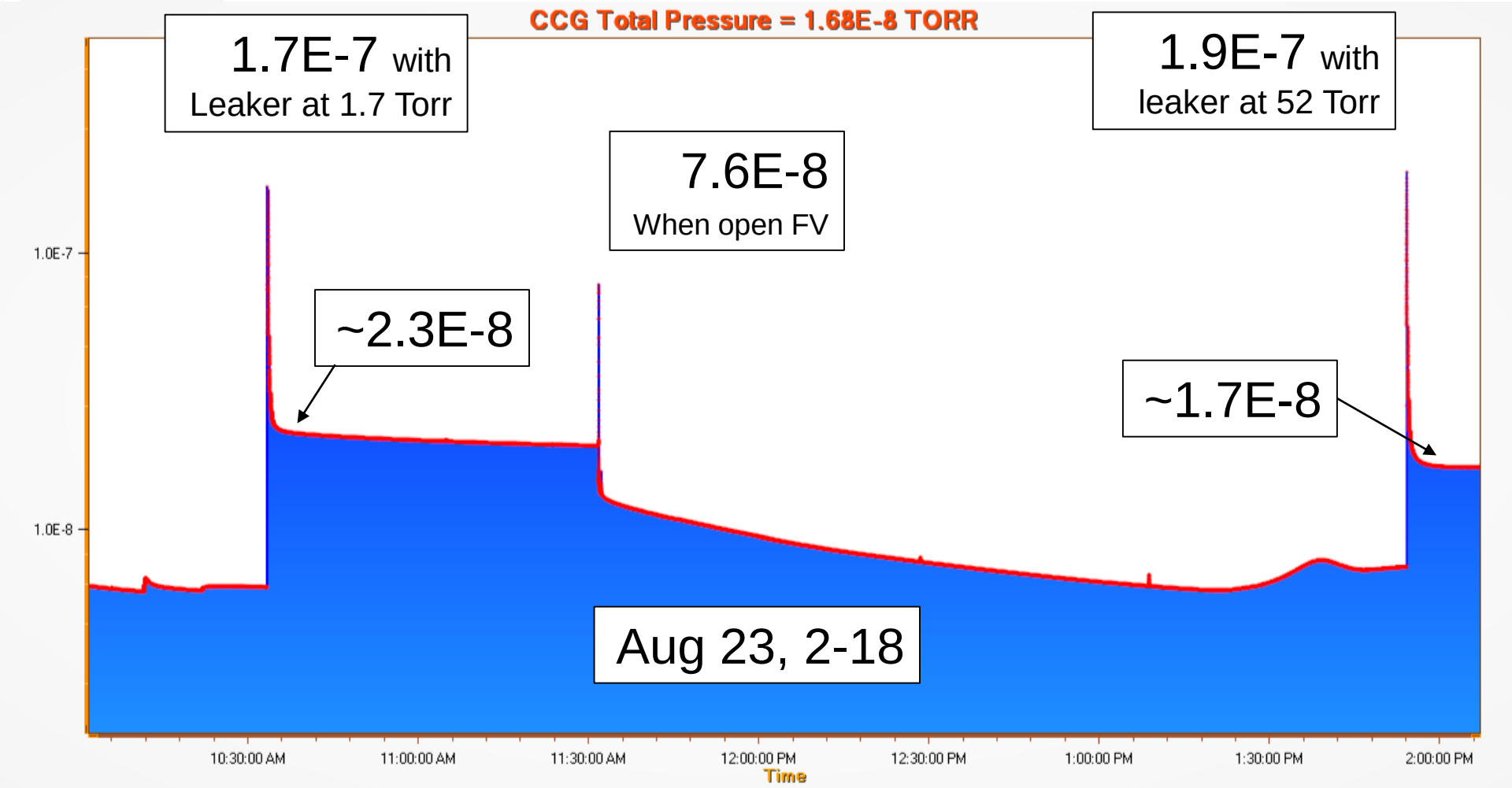
Pressure rise at DS of DPI

DPI significantly reduce gas flux



Fermilab

Vacuum Gauge Reading in Small Volume *(Leak From Upstream of DPI)*

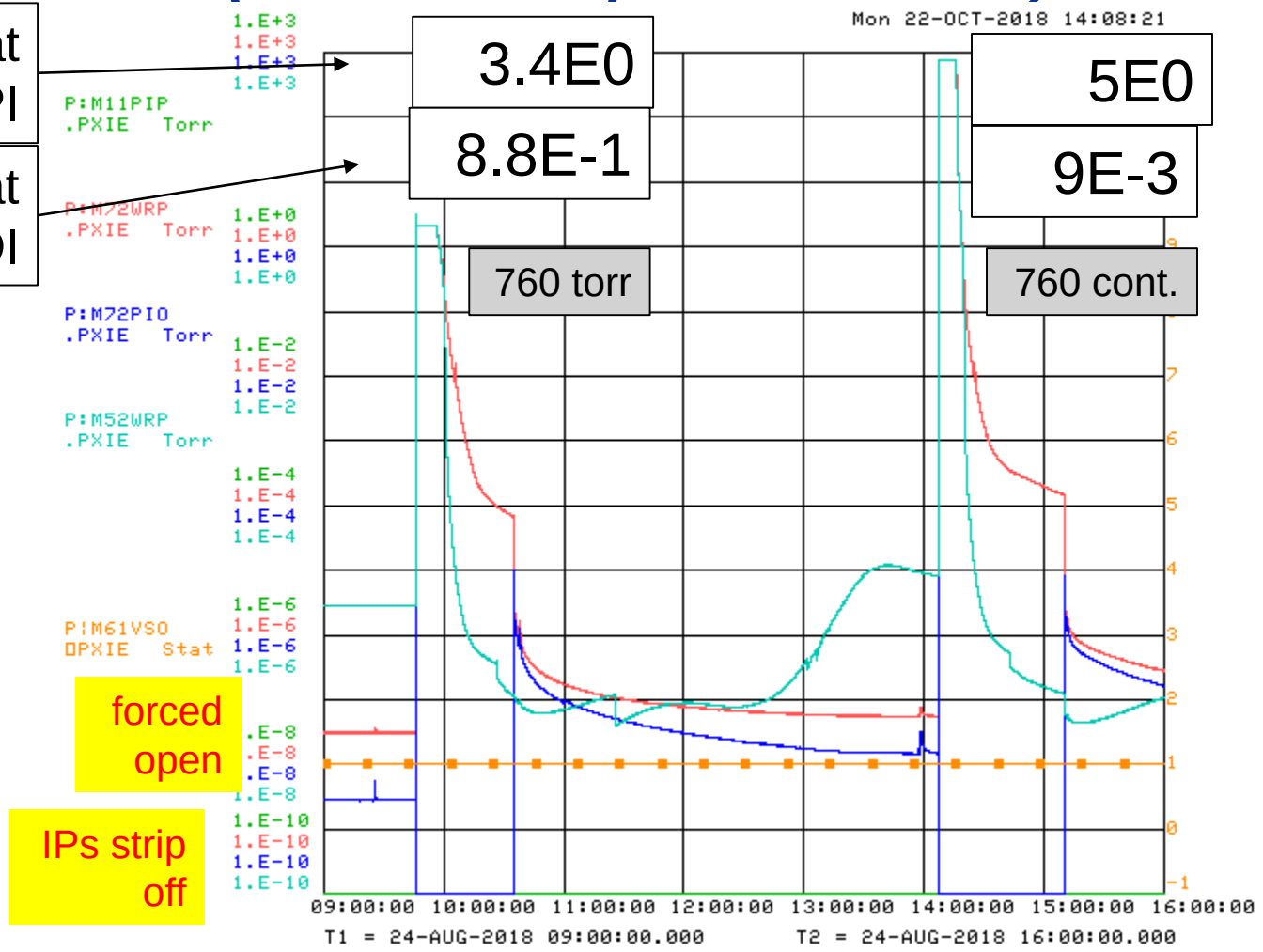


Vacuum Gauge Reading in Small Volume *(Leak From Upstream of DPI)*

Pressure rise at US of DPI

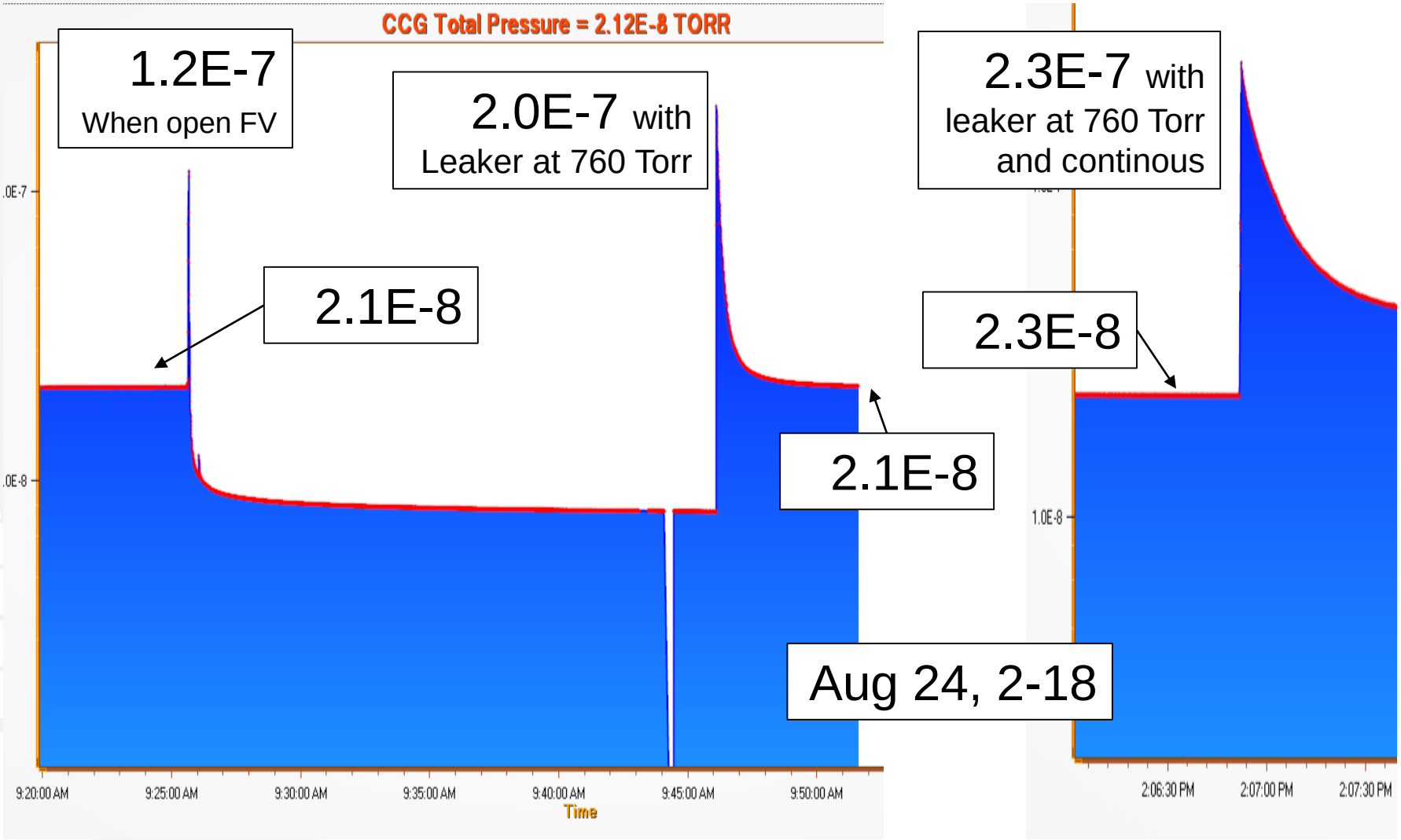
Pressure rise at DS of PDI

DPI effect rapidly vanish in few second due to large leak.

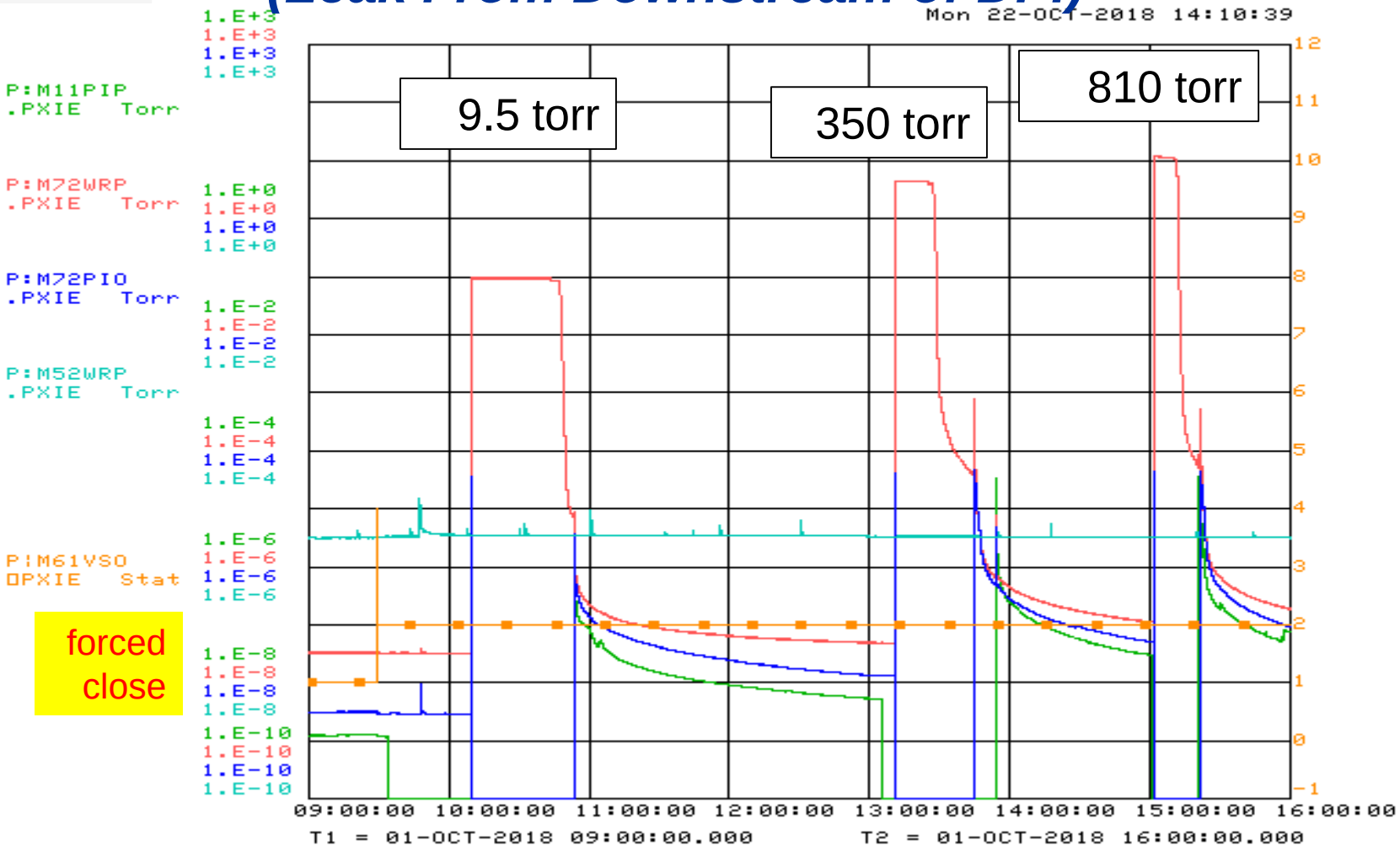


Fermilab

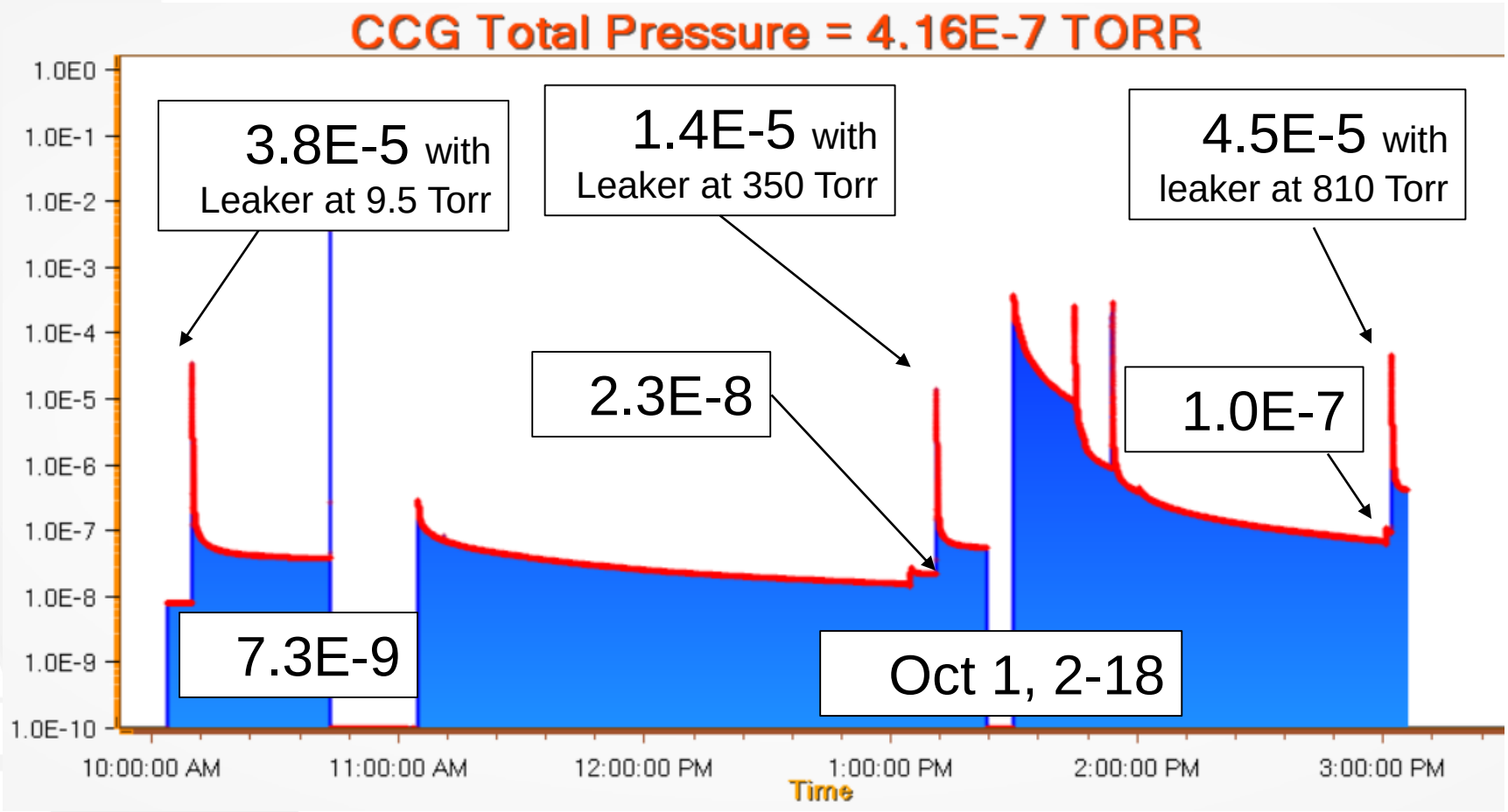
Vacuum Gauge Reading in Small Volume *(Leak From Upstream of DPI)*



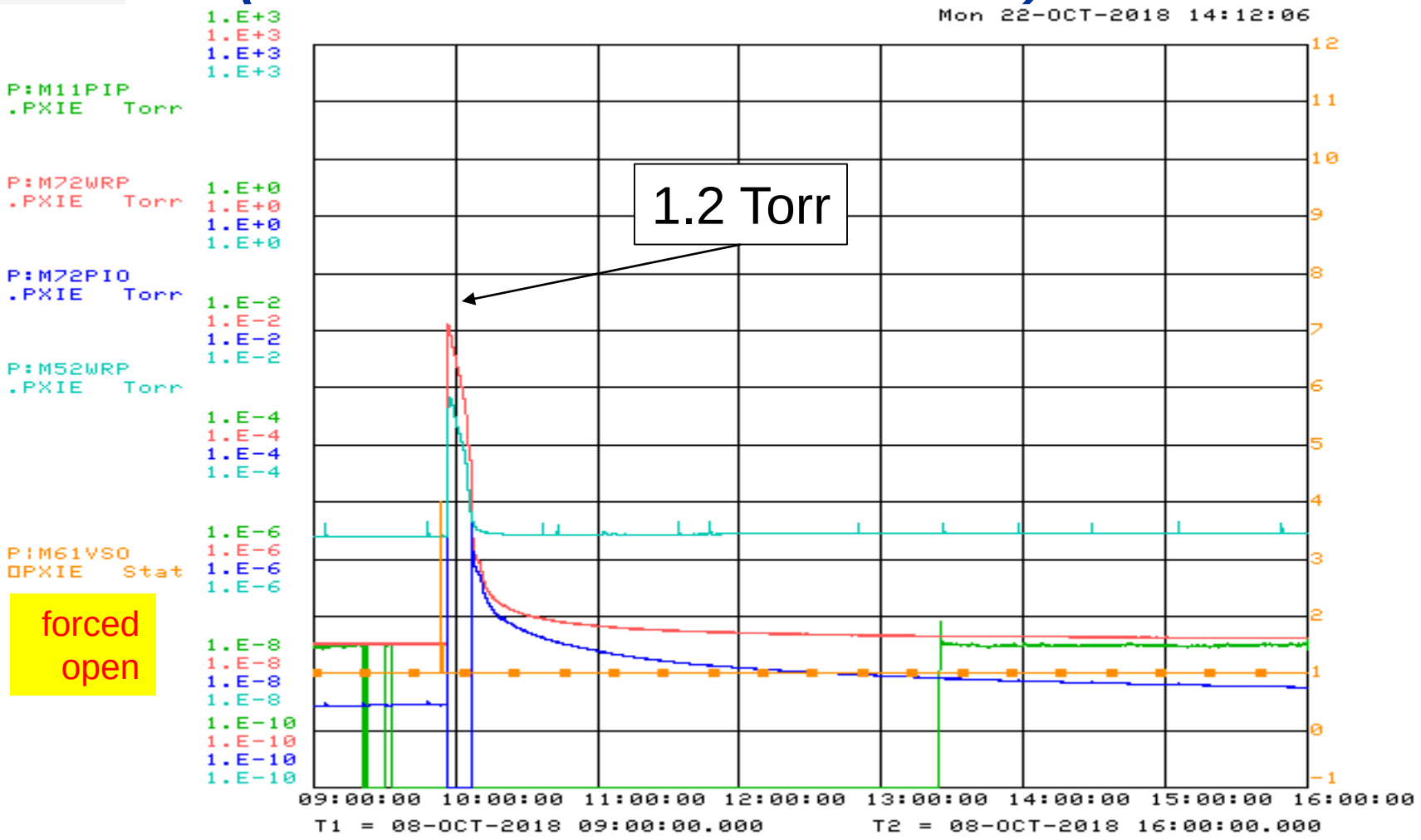
Vacuum Gauge reading on Beamline
(Leak From Downstream of DPI)



Vacuum Gauge Reading in Small Volume *(Leak From Downstream of DPI)*

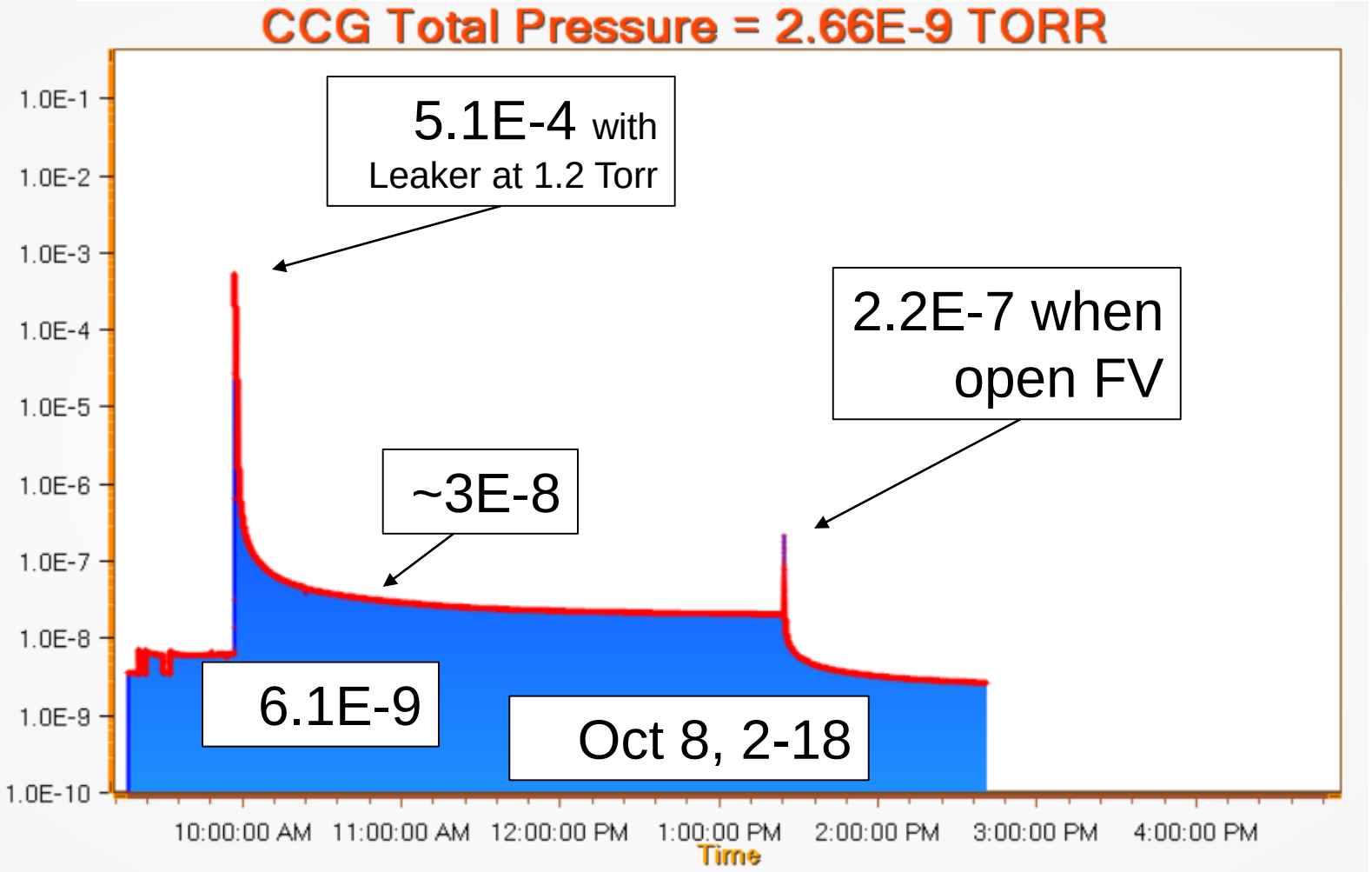


Vacuum Gauge reading on Beamline
(Leak From Downstream of DPI)



forced open

Vacuum Gauge Reading in Small Volume*(Leak From Downstream of DPI)*



Vacuum Gauge reading on Beamline

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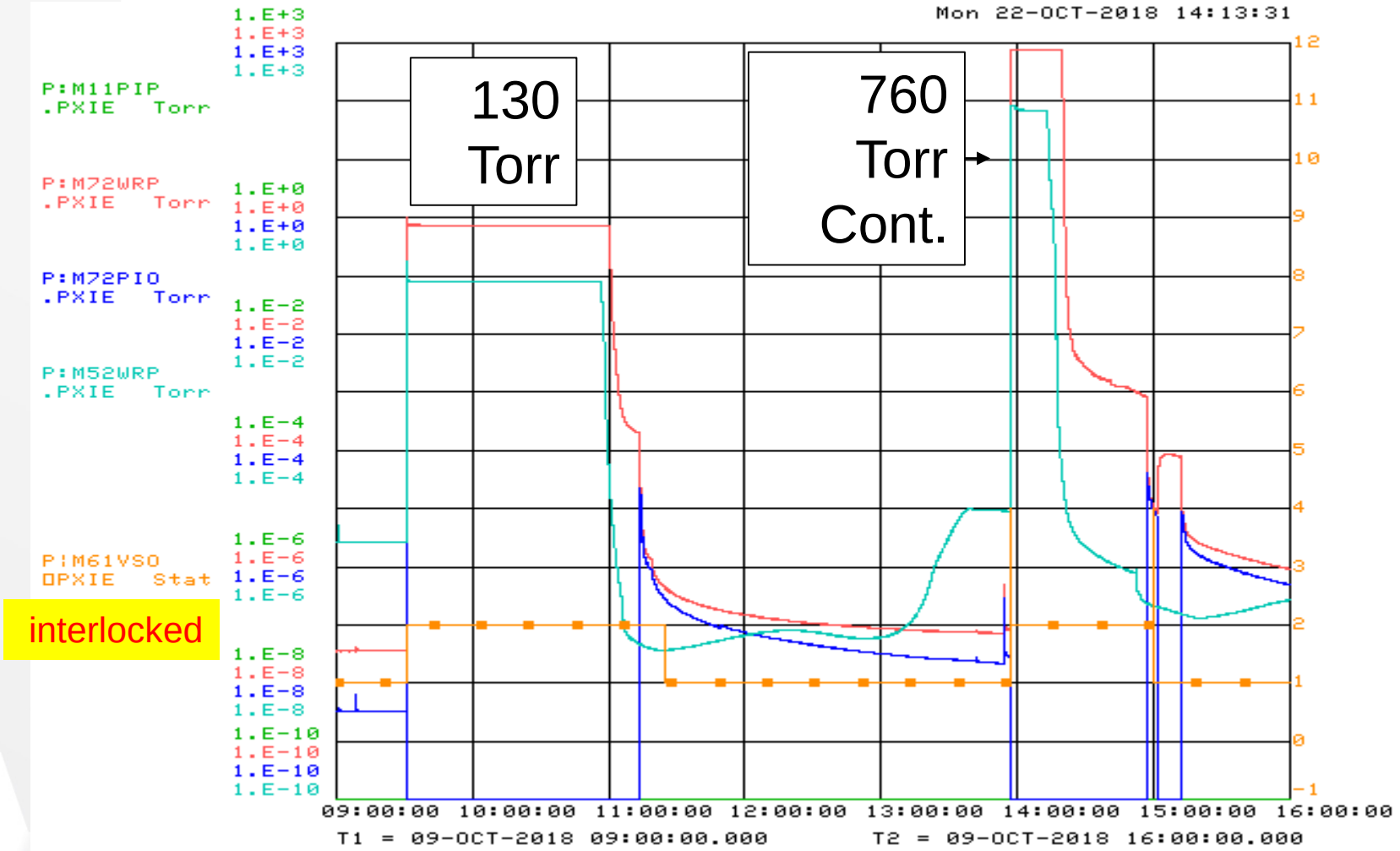
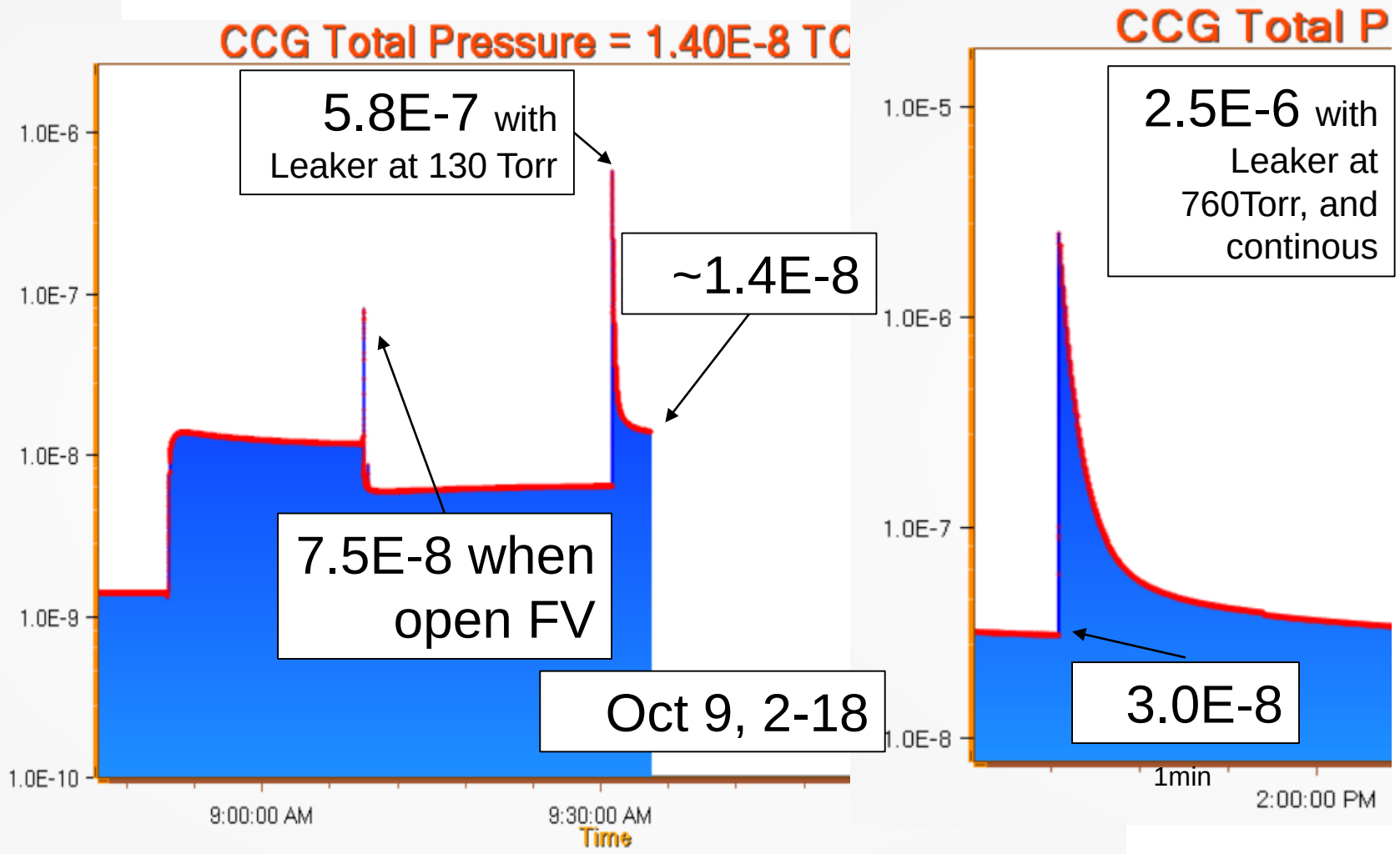
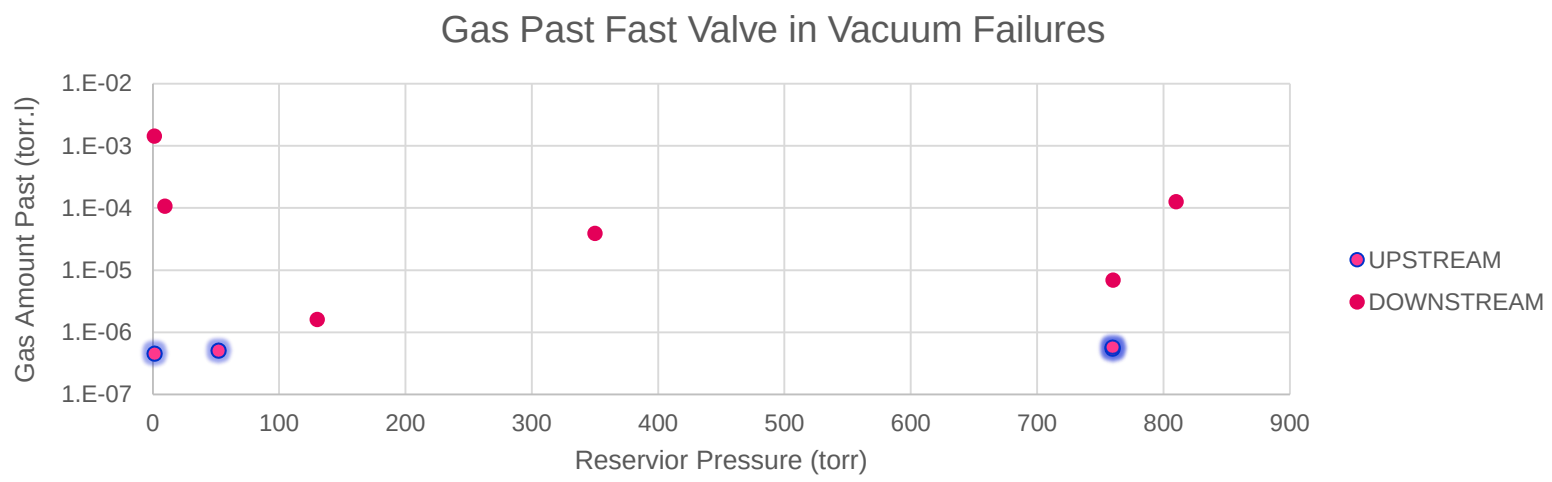


Vacuum Gauge Reading in Small Volume *(Leak From Downstream of DPI)*



Summary of Results

	Leaker Reservoir	CCG500 Reading		dP	Gas Amount	monolayer coverage	Leaker Location
		P0 (before)	P1 (after)				
	torr	torr	torr	torr	torr.liter	cm^2	
23-Aug	1.7	6.2E-09	1.7E-07	1.6E-07	4.6E-07	1.3E-02	US DPI
	52	7.5E-09	1.9E-07	1.8E-07	5.1E-07	1.5E-02	
24-Aug	760	7.9E-09	2.0E-07	1.9E-07	5.4E-07	1.6E-02	
	760	2.3E-08	2.3E-07	2.1E-07	5.8E-07	1.7E-02	
1-Oct	9.5	7.3E-09	3.8E-05	3.8E-05	1.1E-04	3.1E+00	DS DPI
	350	2.1E-08	1.4E-05	1.4E-05	3.9E-05	1.1E+00	
	810	1.0E-07	4.5E-05	4.5E-05	1.3E-04	3.6E+00	
8-Oct	1.2	6.1E-09	5.1E-04	5.1E-04	1.4E-03	4.1E+01	
9-Oct	130	6.0E-09	5.8E-07	5.7E-07	1.6E-06	4.6E-02	
	760	3.0E-08	2.5E-06	2.5E-06	6.9E-06	2.0E-01	



Summary

- DPI-FV protection system functions well in test, meet the requirement.
- The amount of gas past through FV is insignificant in term of monolayer coverage, as result, the peak pressure short lived as soon as gas-surface rebalanced
- The amount of gas past through FV is not directly driven by the size of leak
- Differential Pumping Insert (DPI) throttled the gas flux significantly, about 2 decades.
- Current configuration works, the amount of gas past FV is small enough
  - 1) not able to move particulates,
  - 2) insignificant for surface condensation of cavities

DPI Effect vanishing as larger leaks, however it buys a couple of second of time which is critical to minimizing gas flux into CMs